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A QUANTITATIVE FRACTURE MODEL FOR THE INITIATION OF SUBMARINE LANDSLIDES

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LONG-TERM GOALS

My long term goals are to develop, test, and clearly present new quantitative methods for evaluating stresses in the earth's crust and for understanding fracture or fracture-like phenomena and associated deformation, especially phenomena pertaining to faults and landslides.

SCIENTIFIC OBJECTIVES

The main scientific objectives of the current project are to identify and better understand the factors controlling where submarine landslide slip surface nucleate, how they propagate, and how deformation accumulates in the incipient stages of landsliding.

APPROACH

Elasticity theory, fracture mechanics concepts, and field observations are being combined in this project. Two- and three dimensional boundary element models are used in the analyses.

WORK COMPLETED

A suite of geologic maps, cross-sections, and deformation data on subaerial landslides have been acquired courtesy of William Cotton and Associates and from other sources; this material will serve as analog information to test our model results against.

A three-dimensional boundary element code, POLY3D, has been modified, tested, and shown to satisfactorily match available analytical solutions for a penny-shaped shear fracture. Completion of this work satisfied the remaining M.S. requirement for William Boger. A journal article by Martel and Boger that applies the revised version of POLY3D to secondary fracturing around strike-slip faults has been submitted to the Journal of Geophysical Research.

A series of computer simulations have been conducted to evaluate the elastic stresses in slopes of finite extent under gravitational body forces, including some cases with growing landslide failure surfaces. A two-dimensional boundary element method has been developed to evaluate the elastic stresses in slopes of arbitrary geometry under gravitational body forces.

RESULTS

Landslide failure surfaces appear highly likely to nucleate at or near the surface of a slope, especially at notches in slopes, and to propagate upslope. This new result is consistent with the nature of stress concentrations in a slope and along a shear fracture, and with field observations of landslides. The greatest displacements associated with incipient sliding will occur in the toe region of a slide mass if a failure surface nucleates near the surface of a slope. Landslide failure surfaces that nucleate at depth and then propagate upslope and downslope are prone to develop a more complicated, stepped, geometry than those that nucleate near the surface of a slope.

The size, shape, and orientation of secondary fractures documented around small strike-slip faults can be explained well based on the results from POLY3D elastic modeling.

IMPACT/APPLICATIONS

Two direct applications emerge for avoiding landslide hazards. First, notches in slopes known or suspected to be marginally stable should be avoided; that is where failure surfaces probably nucleate in many cases. Adjacent regions upslope and downslope of prominent notches should be avoided also. Second, monitoring of displacements of slides that are known to be developing should focus on the toe regions, where the displacement "signal" will be largest.

The 2-D boundary element method for analyzing elastic stresses and deformation in slopes of arbitrary shape has widespread application beyond the scope of the current study (e.g., GPS-based deformation surveys, growth of volcanoes, intrusion of dikes through the oceanic crust, stability of boreholes and tunnels). It can be extended to three dimensions using POLY3D.

TRANSITIONS

The POLY3D results are being used in collaborative work with Kevin Hestir and James Evans of Utah State University to develop an inversion method for fluid flow along faults.

RELATED PROJECTS

A project on the three-dimensional hydrogeology of faults, supported by the U.S. Department of Energy, has benefited directly from the work on POLY3D.

REFERENCES

Martel, S.J. and Boger, W.A., Geometry and mechanics of secondary fracturing around small three-dimensional faults, submitted to the Journal of Geophysical Research.

Martel, S.J., and Boger, W.A., 1997, Mechanics of secondary fracturing in three dimensions around small faults: American Geophysical Union Transactions (abstract).

Muller, J., and Martel, S.J., 1997, Nucleation and growth of landslide failure surfaces: American Geophysical Union Transactions (abstract).